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GAGE TIP FORCE TRANSDUCER * B. G. Mills

Have you ever left marks on your parts due to an inspection process? Have you ever received erroneous inspection data because a soft material you are gaging is being scratched and galled by the gage tip? Have you ever asked yourself "What is an acceptable gaging force in this application" or "How much force is being exerted by this gage and is it the same in any orientation?"

These questions were asked at the Rocky Flats Division, and answers were sought from the Mechanical Research and Development department. The first step toward finding a solution was a literature search to find what, if anything, was available to measure the small but significant forces exerted by standard LVDT's, dial indicators, "feather touch", or any of the standard transducers used to measure displacement. Several force transducers were found to be available, but most of them had a minimum resolution of only 30 grams or were sensitive to both orientation and temperature changes when used in the range of interest - 1 to 250 grams. Thus, the decision was made to design and fabricate a force transducer to meet our specific requirements.

The criteria set was: range - 0 to 250 grams; resolution - 1 gram; accuracy - 1 gram; linearity - within 1 gram over

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full scale; orientation sensitivity -less than 1 gram change in reading due to any change in orientation; temperature sensitivity - compensated to meet the above specifications in a temperature range of 40F to 110F. In addition, the device was to be easily calibrated, rugged, and fool proof.

Attempting to meet these criteria, a number of designs were presented. Strain gages mounted on a flexible, spring-type member seemed to offer the most promise. However, when the apparatus was made sensitive enough to measure very small forces, the weight of the spring itself became a significant "load." Since this weight load was directionally independent of the device orientation, the output signal from the device varied with its orientation and, therefore, did not meet the design specification. This problem was finally overcome by the design described below.

In the accepted design (See Fig. I), strain produced in a cantilever leaf spring by an external force is measured by two strain gages mounted on the leaf and acting as variable resistances in a Wheatstone Bridge circuit. An identical "dummy" or compensating leaf mounts two more strain gages which are also part of the bridge circuit. The arrangement is such that any signal generated by the active leaf due to its own weight is automatically

compensated for by a similar signal from the dummy leaf. (See Fig. 2). This removes any effects on the bridge circuit readout due to changes in orientation of the device.

Since the leaves and their strain gages are, for all practical purposes, identical, changes in temperature affect the gages identically. Thus, the bridge circuit, once balanced, is only slightly influenced by temperature (See Fig. 3).

The transducer has met all criteria, and is now being used to find answers to our questions. It was found to be easily and accurately calibrated by using an air bearing (to minimize the effects of friction), a simple platform, and standard balance weights. Most of our standard LVDT's have been checked, and it is anticipated that all gage tips, when they are returned to the Standards Laboratory for calibration, will also be checked for excessive pressures in any orientation.

Figure 4 shows the variation of two LVDT cartridge-type and one "Feather-touch" transducers. It is not unusual for a variation of 30 grams to exist between the two extremes of the transducer tip. An average change of 5 to 10 grams can be expected for different orientations. Differences of 30 to 50 grams are found on supposedly identical transducers. Hysteresis and static friction have been detected in some of the LVDT's.

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FIG. 1. WHEATSTONE BRIDGE AND STRAIN GAGE PLACEMENT

Direct current theory shows that readout voltage "E" in a Wheatstone bridge circuit is:

$$E = V \frac{R_1 R_4 - R_2 R_3}{(R_1 + R_2)(R_3 + R_4)}$$

where V is the reference voltage and R_1 through R_4 are the bridge-arm resistances. If

$$R_1 R_4 = R_2 R_3,$$

it is seen that $E = 0$ and that, for

$$R_1 R_4 \neq R_2 R_3,$$

a finite voltage E is produced.

Four identical strain gages are used as R_1 through R_4 in the force measuring device. Their physical arrangement is shown.

FIG. 2 - LINEARITY CHECK ON FORCE TRANSDUCER

Fig. 3
TEMPERATURE EFFECT

The effective change in "zero" with temperature. The transducer was placed in an environmental chamber; electronic read-out system remained in a $72 \pm 5^\circ\text{F}$ atmosphere.

FIG. 4 - FORCE MEASUREMENTS ON LVDT's

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